

IN SITU SURVEYING OF SATURN'S RINGS

P.E. Clark, M.L. Rilee, L3 Communications GSI
S.A. Curtis, G. Marr, C.Y. Cheung, W. Truszkowski, NASA/GSFC

What are ANTIS and SARA?

ANTIS: Autonomous NanoTechnology Swarm

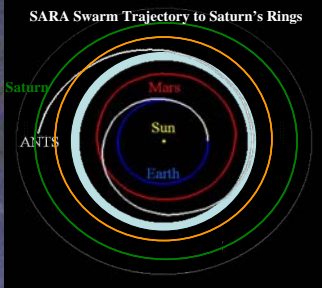
- Inspired by success of social insect colonies where
 - Within their specialties, individuals outperform generalists
 - With sufficiently efficient social interaction and coordination, groups of specialists outperform groups of generalists.
- A Generic Mission Architecture based on:
 - Spatially distributed spacecraft
 - Autonomous, redundant components with high plasticity
 - Hierarchical (multilevel, dense heterarchy) organization

SARA: Saturn Autonomous Ring Array

- ANTIS application to survey dense, dynamic, high G population
 - 1000 spacecraft swarm
 - 10 types of 'specialists' with common spacecraft bus
 - 10 subswarms, ~100 spacecraft each, ~10 each specialist
 - Hybrid propulsion for operation in two regimes:
 - Solar Sail Transport 'Hive Ship' cruise to outer solar system
 - Nuclear Propulsion for individual craft navigate around rings
 - Small nuclear batteries for 100's of milliwatt power requirements
 - Primary objective is in situ exploration of Saturn's Rings to understand formation and origin of planetary systems

SARA Estimated Mission Parameters and Requirements

- Mission Date 2030
- Mission Duration 10 years
- Mission Location Saturn's Rings
- Spacecraft Mass 1-3 kg
- Power System Mass 0.25-1.0 kg
- Power Required 100-300 milliwatts
- Storage Life in Space 10 years
- Spacecraft Attitude 3-axis stable
- Operations:
 - Deep space operations far from Earth & Sun
 - 1 year optimal science operations covering millions of particles
 - Full suite of science instruments deployed in and around ring plane
 - Concurrent operations at hundreds of ring particles
 - No single point of failure; robust to minor faults/catastrophic failures
 - Optimal operations in spite of mission attrition



PAM Concept Development: Current Issues

- The SARA mission concept is an in situ survey of a Saturn's dynamic ring particle population.
 - Such a survey can't be obtained from earth-based observations.
 - Incremental improvements in instrumentation and computer technologies will continue to allow the analysis and dynamic modeling of ring bulk properties from Earth based observations.
 - Current outer planet mission strategies do not allow individual ring particles to be studied.
 - An in situ survey of Saturn's Rings is a challenge unachievable by conventional (direct control of single spacecraft from Earth) or even evolutionary (direct control of multiple spacecraft from Earth surrogate) mission designs.
 - Understanding the origin and dynamics of satellite system formation on Saturn and its relationship to planetary system origin and formation demands correlation of compositional data which can only be obtained by an in situ sampling mission.

Science Objectives for Saturn's Rings

Current Questions

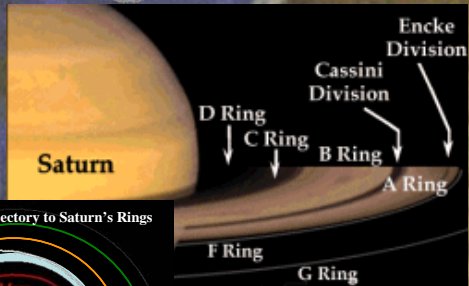
The high density distribution of particles on the scale of particles size, combines with the high intensity gravity and magnetic field environment to produce dynamic plasmas. What are the details of this process?

Although composition is essentially cometary with high volatile abundances, great variations could remain in the dust/gas ratio and the composition of dust component for individual particles. What is the nature of these variations?

SARA Addressing Strategy

Plasma, particle, wave, and field detectors will probably fly just above or below the ring plane to observe the result of particle interactions.

Imagers and spectrometers will need to develop a strategy for serial rendezvous with individual particles through the ring.



PAM Concept Development Methodology

- Develop Conceptual Model for Behavior
 - Neural Basis Function based on bilevel intelligence
 - Combines capability for autonomous and collective behavior
 - Model applies at all levels: component, subsystem, spacecraft, subswarm
 - Individual operational components connect to each other through specially designed interface
- Develop scaled physical models and simulations to illustrate modularity, configurability, scalability
 - Hive ship structure, packaging, and deployment
 - Individual spacecraft structure, deployment from hive
 - Trade study of low expendable propulsion options
- Formulate requirements and operational scenarios driven by high density, dynamic spacecraft size targets with highly volatile composition in high G environment.

PAM Concept Development: Autonomous Assembly

- Autonomous assembly and deployment minimizes resource requirements, including bandwidth and human labor.
- Components are composed of carbon nanotube strands (tethers) or fibers (surfaces) reversibly deployable and stowable from MEMS or NEMS nodes, allowing for orders of magnitude decrease in packaging or stowing volume.
 - A tetrahedron of NEMS nodes forms the basic 'building block'.
 - Assembly is based on creating 2D layers of interconnected NEMS nodes in two patterns.
 - Specialized subsystem nodes can be added to any layer.
 - 2 layers of different pattern form the sail support.
 - A 3 layer sandwich, with different pattern layer in the middle, forms the subsystem platform.
 - Subsystems are tethered together.
 - After assembly, spacecraft are stowed, spooled back into nodes.
 - 1000 autonomous 10 centimeter, 1 kg boxes would stow into a 1 meter, 1000 kg cube.

